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MASTER

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Introduction

One of the significant research interests of the Los Alamos National Laboratory is in the area of "laser fusion development." The Helios laser facility that we will be referring to in this paper ultimately focuses eight high-energy CO_2 laser beams onto a target at the center of a 3.5-m-diam test chamber. During tests, the environment of the chamber is 1×10^{-6} torr vacuum and ambient temperature. An artist's conception of the Helios target chamber is shown in Fig. 1.

Targets used in these experiments are typically 300 μm diam, which necessitates high-precision aligning and positioning techniques for both the targets and the laser beams. The relationship between the laser beams and the targets is accomplished by the Hartmann mask technique.[1] Individual beams are aligned by directing a low-power alignment laser beam through the laser optics. This beam is autocollimated to a kinematically positioned sphere (Hartmann ball) at the chamber center. Figure 2 is a photograph of the inside of the Helios target chamber, showing the target insertion mechanism and the Hartmann ball.

For target location, two orthogonally positioned autocollimating telescopes are aligned to the Hartmann ball. These telescopes are subsequently used to position the target when the Hartmann ball is replaced by the target. The relationship of the telescopes to the target insertion mechanism is shown in Fig. 3. The Hartmann ball is the reference for the optical and physical center of the system.

As experiments became more sophisticated, a requirement for greater flexibility of the system brought about the design of a movable Hartmann ball (MHB) that enabled the laser beams' focal points to be at positions other than the target center. Figure 4 is a photograph of the MHB assembly.

Design Parameters

The design parameters dictated that the Hartmann ball would be movable within a 6-mm cube with 2.5-μm resolution and ±20 μm accuracy. The system must operate in a 1×10^{-6} torr vacuum and employs existing insertion techniques and hardware.

Fig. 1. Artist's conception of Helios target chamber and optical support structure.

Fig. 2. Photograph of inside of Helios target chamber.

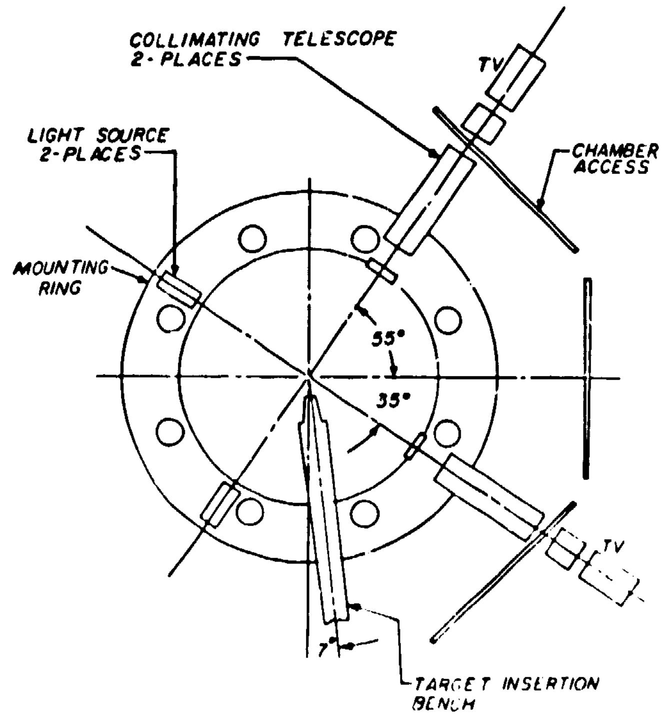

Fig. 3. Autocollimating telescope and target insertion mechanism placement in Helios target chamber.

Fig. 4. Movable Hartmann ball assembly.

The MHB assembly is restricted to less than a 60° cone of space in the target chamber. This profile limitation also influenced design of the original target insertion mechanism so physical profile parameters could not be significantly altered.

Design of the x, y, and z stages uses crossed barrel roller slide assemblies, and motion is accomplished with a 0.5-mm pitch lead screw, coupled to a stepping motor capable of resolving 1000 steps per revolution. This gives a resolution of 0.5 μm per step. To insure that the proper amount of motion has occurred, an encoder mounted on the motor shaft, which also resolves 1000 counts per revolution, feeds back the number of steps the stepping motor actually makes.

A linear slide assembly coupled with motor/encoder exists in each of the x, y, and z axes. Desired motion is preprogrammed and executed using a microprocessor that stores eight positions plus "0" position (bench mark) and allows all the laser beams to have separate focal points.

During the sequence of alignment, the autocollimating telescopes are aligned on the *in situ* Hartmann ball. Once alignment is accomplished, the *in situ* Hartmann ball is replaced by the MHB assembly, which is aligned to the autocollimators. Software counters are set to zero. The MHB is shifted to a preset location. One or more laser beams are now aligned to the new position.

Testing of the MHB

The MHB was tested to determine how accurately the position of the Hartmann ball could be predicted. To perform the test, the MHB was placed on a three-axis measuring machine that was determined to be accurate over 1 m of travel to within 0.5 μm in each axis. The thermal environment in which these measurements were made was controlled to 0.1°F.

The testing procedure consisted of activating one axis at a time and measuring the ball position in all three axes. This yielded a set of calibration curves for the ball position as a function of each axis movement. Multiple-axes movements were then made to determine how well the ball position could be predicted. An example of the calibration curves is shown in Fig. 5. By using the calibration curves, a particular position can be predicted to within ±20 μm. From these data, we also learned that a given position would repeat itself within ±6 μm.

The data that have been taken by the target diagnostic personnel when the MHB is in its working environment have verified the measurements made on the measuring machine.

Conclusions

The MHB has been in operation for about nine months and has been performing quite well. It has provided the Helios laser fusion facility with additional target illumination flexibility so that many additional parameters can be investigated in the realm of target implosion physics.

Reference

1. J. A. Hanlon, M. D. Bausman, M. Caine, M. Calcote, R. L. Carlson, J. J. Hayden, I. Liberman, J. T. Murphy, R. Parnell, R. E. Partridge, J. L. Ray, G. A. Salazar, and H. E. Tucker, "Helios CO_2 Fusion Laser Alignment System," Proceedings of Los Alamos Scientific Laboratory Conference on Optics '79, Los Alamos, New Mexico, May 23-25, 1979 (Bellingham, Washington, 1979), Vol. 190, pp. 186-190.

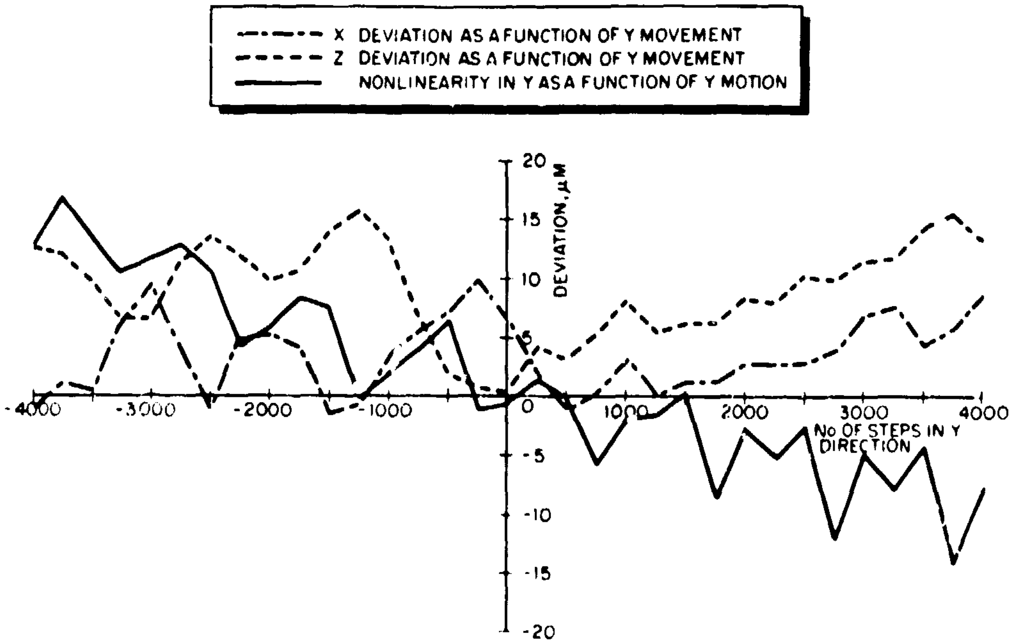

Fig. 5. Y-axis calibration curve for Helios movable Hartmann ball.